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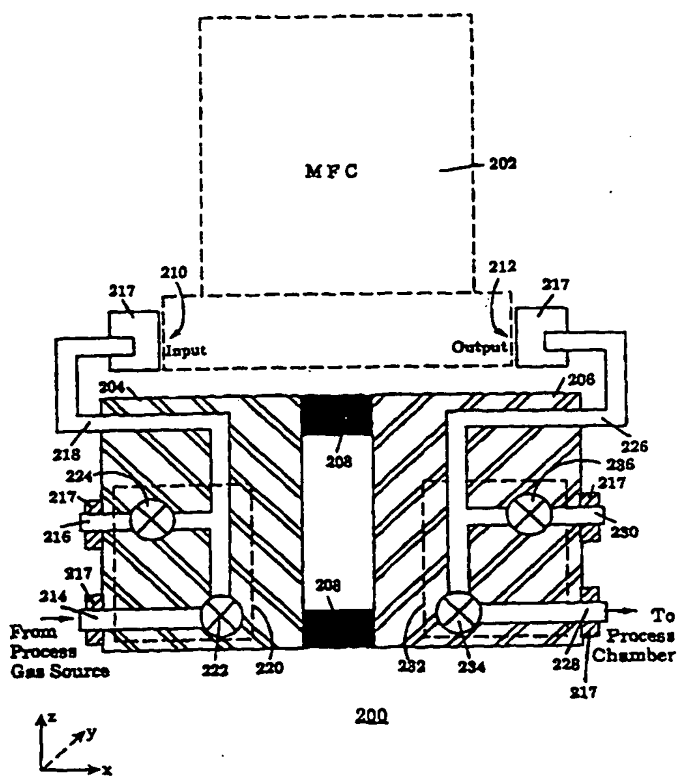
(54) Title: MFC-QUICK CHANGE METHOD AND APPARATUS

(57) Abstract

A quick change method and apparatus (200) for a mass flow controller (MFC) (202). A process gas inlet (214) provides a first process gas to the quick change apparatus (200). An MFC outlet (218) provides a gas from said apparatus to an input of a mass flow controller (202). An upstream purge line (216) provides a purge gas to the quick change apparatus (200). A first means (220) is provided for coupling the process gas inlet (214) to the MFC outlet (218) while isolating the upstream purge line (216) from the MFC outlet (218), and for alternatively coupling the upstream purge line (216) to the MFC outlet (218) while isolating the process gas inlet (214) from the MFC outlet (218). An MFC inlet (226) provides gas to the quick change apparatus (200) from the output (212) of the MFC (202). A process outlet (228) outputs gas from the apparatus (200) to a process chamber. A second means (232) is provided for preventing gas flow from said process outlet (228) to said MFC inlet (226) and for allowing gas flow from said MFC inlet (226) to said process outlet (228).



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MFC - QUICK CHANGE METHOD AND APPARATUS

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

The present invention relates to the field of gas delivery systems and more particularly to equipment and methods used to control gases in semiconductor manufacturing processes.

2. DISCUSSION OF RELATED ART

Today, many modern manufacturing processes use gases wherein the rate of introduction of the gas must be precisely controlled. For example, semiconductor manufacturing processes, such as chemical vapor deposition (CVD), dry etching, and diffusion, all utilize process gases wherein the gas flow (volume/unit time) must be precisely and constantly controlled in order to insure reliable and manufacturable processes. Gas flows are generally controlled by well-known Mass Flow Controllers (MFCs).

A commonly used gas panel 100 of a piece of semiconductor process equipment is shown in Figure 1. A plurality of mass flow controllers 102a - 102d control the flow of a plurality of reactive or process gases A, B, C, and D, used in a manufacturing process. Each MFC feeds a gas into a single process chamber feed line 108 which provides all of the reactive gases to a reaction chamber or tube 110 of a

process tool, such as a CVD reactor. A valve 104a - 104d is generally provided upstream of each MFC for each process gas. Valve 104 allows the source of each reactive gas to be isolated or closed off from its respective MFC. The reactive gases provided to gas panel 100 are generally stored in bottles or tanks 120a - 120d, located in a gas storage room or area 122 away from gas panel 100 and associated semiconductor process equipment. It is to be appreciated that tanks 120a - 120d can be located hundreds of feet away from gas panel 100 requiring literally hundreds of feet of piping to provide gas to gas panel 100. A plurality of valves 106a - 106d and associated piping are generally provided in gas storage area 122 to purge gas panel 100 for maintenance and repair. Gas panel 100 generally includes a purge line 105 and a valve 106e to purge gas panel 100 of reactive gases.

A major weakness with a gas delivery system, such as gas delivery system 100, is that there is no way to quickly replace a failed MFC without first purging the entire gas panel. It is to be appreciated that MFCs constantly fail and are a weak link in most gas delivery systems. To test or replace a single MFC the entire gas panel or delivery system 100 must be isolated and purged. For example, in order to replace MFC 102c in gas panel 100, valves (not shown) on tanks 120a - 120d are closed and purge valves 106a - 106e opened so that an inert purge gas, such as N_2, can be pumped through a large portion of the gas panel for a specified period of time. In gas panel 100 process chamber feed line 108 provides a common connection to all MFCs. The removal of a single MFC 102 provides a passage, through

process chamber feed line 108, for the other gases of the system to leak into the atmosphere. Thus, before a single MFC can be removed, the entire gas panel must be purged. It is to be appreciated that many of the gases used in semiconductor processing are very toxic so that extreme care must be taken to prevent their escape into the atmosphere. Because gas panel 100 contains literally tens of feet of lines which must be completely purged prior to removing a single MFC, the simple removal of an MFC can cost hours of equipment down time and add significant expense to a process.

Another shortcoming of gas delivery system 100 is the inability to test an MFC without first removing the MFC from gas panel 100. Because of the large amount of time and expense necessary to purge an entire gas panel, MFCs are generally not removed to be periodically tested to insure that they provide accurate gas flow readings. Generally a failed or poorly operating MFC is not discovered until it causes noticeable manufacturing problems in the process. For example, a faulty MFC might not be noticed until after a film with the wrong chemical composition or thickness is formed on a wafer or a run of wafers. This can result in a total loss of thousands of dollars of semiconductor devices, and worse allow parts out of process specification, or marginally within process specifications, to remain in the system and presumed to be good parts. Furthermore, any deviations in wafer films are typically blamed on the MFC, and since there is no way to test the MFC in place the MFC is replaced, often

deviations in wafer films are typically blamed on the MFC, and since there is no way to test the MFC in place the MFC is replaced, often unnecessarily. This approach results in substantial and unnecessary expense on process equipment.

Thus, what is needed is a method and apparatus which allows an MFC to be tested while connected into a gas panel and which allows MFCs to be removed and replaced without purging the entire gas panel.

SUMMARY OF THE INVENTION

A quick change method and apparatus for a mass flow controller (MFC) is described. The quick change apparatus of the present invention allows an MFC to be quickly and easily removed and replaced without effecting or contaminating other components of the gas panel to which it is coupled. Additionally, the quick change apparatus of the present invention allows an MFC to be tested while connected into a gas panel. A process gas inlet provides a first process gas to the quick change apparatus. An MFC outlet provides gas from said apparatus to an input of a mass flow controller. An upstream purge line provides a purge gas to the quick change apparatus. A first means is provided for coupling the process gas inlet to the MFC outlet while isolating the upstream purge line from the MFC outlet, and for alternatively coupling the upstream purge line to the MFC outlet while isolating the process gas inlet from the MFC outlet. An MFC inlet provides gas to the quick change apparatus from the output of the MFC. A process outlet outputs gas from the apparatus to a process chamber. A second means is provided for preventing gas flow from said process outlet to said MFC inlet and for allowing gas flow from said MFC inlet to said process outlet.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is an illustration of a typical gas panel of a semiconductor process equipment.

Figure 2 is an illustration of a Mass Flow Controller (MFC) Quick Change apparatus of the present invention.

Figure 3 is an illustration of a gas panel with a Mass Flow Controller (MFC) Quick Change apparatus of the present invention

Figure 4a is an illustration of a normal operating mode of the MFC-Quick Change apparatus of the present invention.

Figure 4b is an illustration of a first purge/test mode of the MFC-Quick Change apparatus of the present invention.

Figure 4c is an illustration of a second purge/test mode of the MFC-Quick Change apparatus of the present invention.

Figure 4d is an illustration of a removal mode of the MFC-Quick Change apparatus of the present invention.

Figure 5 is an illustration of an alternative embodiment of the quick change apparatus of the present invention.

Figure 6a is a timing diagram illustrating a preferred method of use of the quick change apparatus of the present invention.

Figure 6b is a timing diagram illustrating a preferred method of use of the quick change apparatus having a sinlge connection to the upstream and downstream purge lines.

Figure 7a is an illustration of an acuator which can be used to control the opening and closing of valves in the quick change apparatus of the present invention.

Figure 7b is an illustration of how the actuator of Figure 7a can be implemented into the quick change apparatus of the present invention

DETAILED DESCRIPTION OF THE PRESENT INVENTION

A novel method and apparatus for controlling a gas in semiconductor processes and equipment is described. In the following description numerous specific details are set forth in order to provide a thorough understanding of the present invention. In other instances, well-known semiconductor processes and equipment have not been explained in any specific detail in order to not unnecessarily obscure the present invention.

A novel quick change apparatus 200 of the present invention is shown in Figure 2. The novel quick change apparatus 200 of the present invention is preferably utilized to couple a Mass Flow Controller (MFC) 202 into a gas panel or distribution system. For example, quick change apparatus 200 can be used to couple an MFC into a gas panel of a piece of a semiconductor process equipment. Quick change apparatus 200 allows for removal and replacement of an MFC without contaminating or effecting other portions of the gas system to which it is connected. Quick change apparatus 200 also allows an MFC to be tested in place (i.e., while connected into a gas system). The novel method and apparatus of the present invention lowers process cost by reducing expensive equipment down time associated with testing and replacing an MFC.

As shown in Figure 2, quick change apparatus 200 of the present invention comprises two symmetrical blocks or housings 204 and 206 connected together by coupling 208. Block or housing 204 is the input

portion of quick change apparatus 200 and is connected to the gas input 210 of MFC 202. Block or housing 206 is the output portion of quick change apparatus 200 and is coupled to the gas output 212 of MFC 202.

Input block 204 is preferably comprised of a stainless steel block with a process gas inlet line or passage 214, a local upstream purge line 216, and an MFC output line 218. Process gas inlet 214 is used to provide a process gas to quick change apparatus 200. MFC output line 218 is used to provide a gas from quick change apparatus 200 to the gas input 210 of MFC 202. Local upstream purge line 216 is used to provide a purge gas directly to quick change apparatus 200.

Input block 204 also comprises valving 220, or equivalent means, having at least two modes of operation. Valving 220 has a first mode which couples process gas inlet line 214 to MFC output line 218 while isolating local upstream purge line 216 from MFC output line 218, and a second mode which couples local purge gas inlet line 216 to MFC output line 218 while isolating process gas inlet line 214 from MFC output line 218. Presently, valving 220 is implemented with two two-way valves. A process gas inlet valve 222 is situated between process gas inlet line 214 and MFC output line 218, and a local upstream purge valve 224 is situated between local upstream purge line 216 and MFC output line 218. It is to be appreciated, however, that other well-known means, such as a three-way valve, can be utilized to implement valving 220 in the quick change apparatus of the present invention.

According to the preferred embodiment of the present invention, output block 206 is a symmetrical version of input block 204. The symmetrical nature of quick change apparatus 200 simplifies and reduces its manufacturing costs. Output block 206 is preferably a stainless steel block with an MFC inlet 226 and a process gas outlet 228. Output block 206 also preferably includes a local downstream purge line 230. MFC inlet 226 is used to provide a gas from gas output 212 of MFC 202 to quick change apparatus 200. Process gas outlet 228 is used to output a gas from quick change apparatus 200 to a process chamber feed line. Local downstream purge line 230 is used to directly exhaust or output a local purge gas from quick change apparatus 200.

Like input block 204, output block 206 preferably has valving 232, or equivalent means, having at least two modes of operation. Valving 232 has a first mode which couples MFC inlet 226 to process gas outlet 228 while isolating local downstream purge line 230 from MFC inlet 226 and a second mode which couples local downstream purge line 230 to MFC inlet 226 while isolating process gas outlet 228 from MFC inlet 226. Like valving 220, valving 232 is presently preferably implemented with two two-way valves. A process gas outlet valve 234 is placed between MFC inlet 226 and process gas outlet 228, and a local downstream purge valve 236 situated between local downstream purge line 230 and MFC inlet 226. Like valving 220, valving 232 can be implemented with other well-known techniques, such as a three-way valve, without departing from the scope of the present invention.

Although the present invention preferably includes a local purge gas outlet and two two-way valves, local downstream purge line 230 is not necessary to practice the invention. If local downstream purge line 230 is not included valving 232 can be implemented with a two-way valve between MFC outlet line 218 and MFC inlet line 226. In an alternative embodiment of quick change apparatus 200, local upstream purge line 216 and local downstream purge line 230 are connected together to provide a single external connection 502 for both the upstream and downstream purge lines, as shown in Figure 5.

According to the present invention, each gas line 214, 216, 218, 226, 228, and 230 is preferably a 0.18 inch passage drilled in stainless steel block 204 and 206, respectively. Additionally, all surfaces are preferably electropolished to prevent corrosion and to provide an ultra clean environment. Additionally, all valves 222, 224, 234, and 236 used in the present invention are preferably vacuum-tight valves with valve seats which are able to withstand gas pressures of at least 200 psi and gas temperatures ranging from 0°C - 70°C. Valves 222, 224, 234, and 236 can be either manually switched valves or automatically switch valves, such as pneumatic valves. It is to be appreciated that any well-known valve which can provide an adequate air tight seal, such as diaphragm valves manufactured by A. P. Technology, Nupro Company, Veriflow Corporation, and Fujikin, can be utilized in the present invention.

Although not shown in Figure 2, the preferred embodiment of the quick change appartus 200 includes an actuator which resides

between input block 204 and output block 206. The actuator controls the opening and closing of valves in a preferred manner explained later.

Additionally, according to the present invention, quick change apparatus 200 is coupled externally by well-known air tight metal seal connection 217 to MFC 202 and other external gas lines. Additionally, process gas inlet 214 and outlet 228 are preferably connected into a gas panel with air-tight metal seal connections similar to those used in other areas of the gas panel. It is appreciated, however, that any well-known connection can be used for external connection 217, such as a VCR connection manufactured by Cajon. Additionally, it may be desirable to use quick change disconnects on local upstream purge line 216 and local downstream purge line 230. Stainless steel tubing or fixtures can be used to couple blocks 204 and 206 to MFC 202.

Figure 3 shows the use of a plurality of quick change apparatuses 200a - 200d in a typical gas panel 300 of a piece of semiconductor process equipment. A plurality of process or reactive gases A, B, C, D, etc. are provided to gas panel 300 from a plurality of gas sources, such as tanks or bottles 320a - 320d located in a gas storage area 322 away from gas panel 300 and process chamber 308. The source of each process gas is coupled to an individual source gas valve 302a - 302d, respectively, located in gas panel 300. Source gas valves 302a - 302d are used to either couple or isolate the source of process gases A - D to or from process gas inlets 214a - 214d of quick change apparatuses 200a - 200d, respectively, in gas panel 300.

Coupled to each quick change apparatuses 200a - 200d is a mass flow controllers 202a - 202d, respectively. MFC 202a - 202d can be any well-known MFC, such as those manufactured by Unit Instruments or Tylan General. Coupled downstream of the process gas outlets 228a - 228d of each quick change apparatuses 200a - 200d is a single process gas feed line 304. Process gas feed line 304 combines the outputted gases from the quick change apparatuses 200a - 200d and provides them to a process chamber or tube 308 of a piece of process equipment, such as a chemical vapor deposition (CVD) reactor, or a plasma etcher. It is to be appreciated that each quick change apparatuses 200a - 200d in the present invention is coupled upstream of process gas feed line 304 and downstream of each source gas valve 302a - 302d, respectively. A process gas feed line valve 306 can be provided to either couple or isolate process gas feed line 304 to process chamber 308.

A system purge gas, such as N_2, is also provided to gas panel 300 from a purge gas source 324. A plurality of system purge valves 310a - 310d and associated purge lines are provided in gas storage area 322 to allow a system purge of gas panel 300. System purge gas valve 310e is used to alternatively couple or isolate the source of system purge gas to and from process tool feed line 304.

During normal operation of gas panel 300, all system purge gas valves 310a - 310e are closed and all source gas valves 302a - 302d are open. In order to provide a system purge of gas panel 300, some or all of the valves (not shown) on bottles 320a - 320d are closed and respective system purge gas valves 310a - 310d are open, as is system

purge gas valve 310e. In this way, gas panel 300 can be purged of reactive gases A - D in a typical manner known in the art.

According to the preferred embodiment of the present invention, quick change apparatus 200, is constructed to fit within the minimum standard footprint, (width (y) • length (x)) of 1.5 inches in width by 4.88 inches in length, generally provided in most gas panels for the smallest MFCs. In this way, quick change apparatus 200 and an MFC coupled to it can be easily placed within the location generally provided for an MFC alone, without requiring additional alterations to gas panel 300. Additionally, a valuable feature of quick change apparatus 200 is that it is comprised of two symmetrical blocks coupled together by a variable length coupling 208. Variable length coupling 208 allows the length (x) of quick change apparatus 200 to be extended to precisely fit within standard spaces provided for larger MFCs (i.e., 1.5" • 6.35"). In this way, quick change apparatus 200 is versatile and compatible with almost all gas systems. Additionally, quick change apparatus 200 is preferably constructed with a maximum height (z) of approximately 3.0 inches. Because of its compact size, quick change apparatus 200 consumes very little space in gas panel 300.

Additionally, it is to be appreciated that the location and size of quick change apparatus 200 allows for local isolation and direct purging of MFC 202. With quick change apparatus 200, the removal of a single MFC requires purging of only inches of passages or lines, as opposed to tens or hundreds of feet typically required in many gas panels, such as gas panel 100. Thus, with the quick change apparatus of

the present invention, an MFC can be safely removed from a gas panel in minutes, as opposed to hours, and expensive equipment down time, normally associated with removing an MFC, can be eliminated.

Figures 4a - 4d are schematic drawings illustrating several different modes of operation of quick change apparatus 200 while connected into gas panel 300.

Figure 4a illustrates a normal operation mode of quick change apparatus 200. In the normal operation mode of quick change apparatus 200
both local upstream purge valve 224 and local downstream purge valve 236 are closed to seal off and isolate local upstream purge line 216 and local downstream purge line 230 from MFC outlet 218 and MFC inlet 226, respectively. Additionally, in normal operation mode process gas inlet valve 222 and process gas outlet valve 234 are open. In this way a process gas (or a system purge gas) flows from the gas source coupled to process gas inlet 214 through valve 222, and MFC outlet 218 into MFC 202, where the gas flow is controlled, and then flows out through MFC inlet 226, valve 234 and out process gas outlet 228 to a process tool feed line.

Figure 4b illustrates a first purge/test mode of quick change apparatus 200. In this mode process gas inlet valve 222 and local downstream purge valve 236 are closed while local upstream purge valve 224 and process gas outlet valve 234 are open. In this way the process gas coupled to quick change apparatus 200 is locally isolated from MFC 202. A purge or test gas, such as N_2, can then be fed

through local upstream purge line 216, through local upstream purge valve 224 and through MFC outlet 218 into MFC 202 and then flow out through MFC inlet 226, valve 234, and process gas outlet 228 to a process tool feed line where it is exhausted through normal exhaust lines. In this mode of operation, MFC 202 can be locally isolated and directly purged of reactive gases without purging the entire gas panel 300. This mode of operation can be used to decontaminate an MFC prior to removal of the MFC.

Additionally, the purge/test mode of operation illustrated in Figure 4b, can be used to test in place MFC 202 (i.e., tested in-situ). This can be accomplished by coupling a test gas source and a test device (having a properly working MFC) to local upstream purge line 216. The test gas is then flowed through the test device which provides an accurate reading of the actual gas flow which can be compared to the gas flow read by MFC 202 to determine if there are any inaccuracies. In this way a degraded MFC can be detected prior to creating significant and expensive downstream process problems. Additionally, in this way, MFC 202 can be continually tested to determine its adequacy and to track its performance. This mode also introduces the possibility of periodic and preventative monitoring and maintenance not previously possible without effecting other portions of gas panel 300.

Figure 4c illustrates a second purge/test mode of operation of quick change apparatus 200. In the second purge/test mode both process gas inlet valve 222 and process gas outlet valve 234 are closed

while both local upstream purge valve 224 and local downstream purge valve 236 are open. Next, a local purge or test gas can be connected to local upstream purge line 216 and flowed through local upstream purge valve 224 and MFC outlet 218 into MFC 202 and out through MFC inlet 226, local downstream purge valve 236, and local downstream purge line 230. In this way, MFC 202 can be locally isolated from gas panel 300 and tested or purged without effecting other lines or MFCs of gas panel 300. It is to be appreciated that in this mode of operation gas is not exhausted through gas panel lines and no other interruption to gas panel 300 is experienced. If the second purge/test mode is utilized to decontaminate or purge MFC 202 of a reactive gas which is toxic or hazardous, care must be taken to insure that all gas is collected at local downstream purge line 230.

The purge modes, shown in Figures 4b and 4c, allow quick change apparatus 200 and MFC 202 to be cycle-purged. In a cycle purge operation using the first purge/test mode shown in Figure 4b, process gas outlet 228 is alternately connected to exhaust and vacuum. In the first part of the cycle, local upstream purge valve 224 and process gas outlet valve 234 are open and purge gas is flowed from local upstream purge line 216 to process gas outlet 228 and exhausted through normal exhaust lines of the system. In the second part of the cycle, local upstream purge valve 224 is closed and process gas outlet 228 is aligned to a vacuum source. Thus, purge gas which filled quick change apparatus 200 and MFC 202 is exhausted to vacuum. Local upstream purge valve 224 then is opened to repeat the first part of the

cycle where fresh purge gas is allowed to flow through the quick change apparatus 200 and MFC 202. Successive cycles of creating a vacuum and backfilling are repeated until quick change apparatus 200 and MFC 202 are sufficiently purged.

In a cycle purge operation using the second purge/test mode shown in Figure 4c, local downstream purge line 230 is alternatively connected to exhaust and vacuum. In the first part of the cycle, local upstream purge valve 224 and local downstream purge valve 236 are open and a purge gas is flowed from local upstream purge line 216 to local downstream purge line 230. In the second part of the cycle, local upstream purge valve 224 is closed and local downstream purge line 230 is aligned to a vacuum source, and the purge gas which filled quick change apparatus 200 and MFC 202 is exhausted to vacuum. Local upstream purge valve 224 then is opened to repeat the first part of the cycle where fresh purge gas is allowed to flow through the quick change apparatus 200 and MFC 202. Successive cycles of creating a vacuum and backfilling are repeated until quick change apparatus 200 and MFC 202 are sufficiently purged. The cycle purge operations described above produce a very efficient and thorough purging of quick change apparatus 200 and MFC 202.

Figure 4d illustrates a removal mode of quick change apparatus 200. In the removal mode, both process gas inlet valve 222 and process gas outlet valve 234 are closed in order to locally isolate MFC 202 from gas panel 300. Additionally, in the removal mode, local upstream purge valve 224 and local downstream purge valve 236 are

open. After MFC 202 and quick change apparatus 200 have been sufficiently purged, MFC 202 can be removed by placing quick change apparatus 200 is in the removal mode. While MFC 202 is removed from quick change apparatus 200, a source of an inert purge gas is preferably connected to both local upstream purge line 216 and local downstream purge line 230, and flowed through valves 224 and 236 and out MFC outlet 218 and MFC inlet 226, respectively, as shown in Figure 4d. In this way, no contaminants from the atmosphere can seep into and contaminate quick change apparatus 200 while MFC 202 is removed.

Figure 6a is a timing diagram which illustrates a preferred method of use of quick change apparatus 200. Figure 6a illustrates a preferred method of purging, testing, replacing, installing, and decontaminating an MFC. As shown in Figure 6a, quick change apparatus 200 is initially (time T_0) in the normal operation mode or "flow through" mode described with respect to Figure 4a. In the "flow through" mode, process gas inlet valve 222 and process gas outlet valve 234 are opened and upstream and downstream valves 234 and 236 are closed. In order to purge, test, or replace an MFC, a purge line, for providing a purge gas, is first connected to upstream purge line 216. Additionally, an exhaust line, for exhausting the purge gas and any toxic gases, is connected to downstream purge line 230. Next, during time T_1, process gas inlet and outlet valves 222 and 234 are closed and local purge valves 224 and 236 are opened. In order to place

quick change apparatus 200 in the purge/test mode, described with respect to Figure 4c.

A valuable feature of the preferred embodiment of the present invention is the manner and timing in which valves 222, 224, 234, and 236 are opened and closed. In the preferred embodiment of the present invention, an actuator is provided which controls the opening and closing of valves 222, 224, 234, and 236 in quick change apparatus 200. The actuator allows valves to be opened and closed only in the manner described below. In this way, toxic gases are prevented from escaping into the atmosphere due to operation error. Additionally, the actuator prevents accidental contamination of upstream and downstream gas lines.

According to the preferred embodiment of the present invention as shown in Figure 6a, process gas inlet valve 222 and process gas outlet valve 234 are first simultaneously closed to isolate the MFC from the gas panel to which it is connected. Only after both purge valves 222 and 234 are completely closed can downstream purge valve 236 begin to open. After downstream purge valve 236 is slightly opened (approximately half way), upstream purge valve 224 begins to open. Once upstream purge valve 224 is about half way open, downstream purge valve 236 is completely opened. After downstream purge valve 236 is fully opened, upstream purge valve 224 is completely opened.

In the preferred embodiment of the present invention, the actuator prevents upstream purge valve 224 and downstream purge

valve 236 from opening until quick change apparatus 200 is completely isolated from the gas panel to which it is attached. In this way, no toxins or contaminates can accidentally be released into the atmosphere by an operator error. Additionally, by first slightly opening downstream purge valve 236 prior to opening upstream purge valve 224, downstream pressure is released from within the MFC and quick change apparatus 200 so that the purge gas line attached to the upstream purge line is not contaminated.

Once process gas inlet and outlet valves 222 and 234 are completely closed and purge valves 224 and 236 are open, the MFC can be purged, tested, and replaced. If necessary, a new MFC can be installed and decontaminated at this time. First, as shown in Figure 6a, the MFC and quick change apparatus 200 are completely purged by flowing a purge gas, such as N_2, through upstream purge line 216 through the MFC and out the downstream purge line 230 and into the exhaust line to which it is coupled. Once the MFC has been sufficiently purged, the MFC can be tested by flowing a gas through the MFC to check the MFC's accuracy. If it is determined that the MFC should be replaced, the downstream purge line 230 is realigned from the exhaust line to a purge gas source (such as upstream purge line 216).

Next, a slight flow of N_2 is initiated through upstream and downstream purge lines 216 and 230, respectively. The old MFC is then removed from quick change apparatus 200. While MFC 202 is removed, purge gas is flowed through quick change apparatus 200, as

illustrated in Figure 4d. In this way no contaminates can seep from the atmosphere into quick change apparatus 200 while the MFC is removed. Once a new MFC is installed and securely connected back into quick change apparatus 200, downstream purge line 230 is realigned from the purge gas source to the exhaust line. Next, the new MFC is decontaminated by flowing a purge gas through upstream purge line 216 through the new MFC and out downstream purge line 230.

After sufficient decontamination of the new MFC, valves 222, 224, 234, and 236 are switched from the purge/test mode of Figure 4c to the normal operation mode of Figure 4a. As before, the Actuator of the present invention controls the switching of the valves from the purge/test mode of Figure 4c to the normal operation mode of Figure 4a. As shown in Figure 6a, the actuator first slightly closes upstream purge valve 224. Once upstream purge valves 224 is approximately half closed, downstream purge valve 236 begins to close. When upstream purge valve 224 is completely closed, downstream purge valve 236 is approximately half closed. After downstream purge valve 236 is completely closed, process gas inlet valve 222 and process gas outlet valve 234 are simultaneously opened placing quick apparatus 200 in the normal operating mode shown in Figure 4a. It is to be appreciated that the actuator incorporated into quick change apparatus 200 prevents the opening of process gas inlet and outlet valves 222 and 234 prior to the complete closing of purge gas valves 224 and 236. At this time the new MFC is ready for use.

As is quite evident from Figure 6a, utilizing the quick change apparatus of the present invention, one can easily test, purge, replace and decontaminate an MFC with very little effort and without effecting other components of the gas system. Additionally, by allowing valves 222, 224, 234, and 236 to be opened and closed only in the order and manner described above, potential hazards due to operator error are eliminated.

Figure 6b is a timing diagram illustrating a preferred method of use of quick change apparatus 200 shown in Figure 5, where there is a single connection 502 to upstream and downstream purge lines 216 and 230, respectively. As shown in Figure 6b, initially quick change apparatus 200 is in the normal mode of operation with process gas inlet valve 222 and process gas outlet valve 234 in the open position, and local upstream purge valve 224 and local downstream purge valve 236 in the closed position. In order to test or replace an MFC, a purge gas line is first coupled to connection 502. Next, process gas inlet valve 222 is completely closed. Once process gas inlet valve 222 is completely closed, local upstream purge valve 224 is opened. When local upstream purge valve 224 begins to open, a purge gas is flowed through valve 224, through the MFC, and out process gas outlet 228 to the system exhaust, as shown in Figure 4b. After the MFC has been sufficiently purged, it can be tested to determine if it should be replaced.

If the MFC is to be replaced, local downstream purge valve 236 is open simultaneously as process gas outlet valve 234 is closed. Next,

the MFC is removed. While the MFC is removed, purge gas is flowed through the upstream and downstream purge lines 216 and 230, as shown in Figure 4d, in order to prevent contaminates from seeping into quick change apparatus 200. Once a new MFC is securely fastened into quick change apparatus 200, local downstream purge valve 236 is closed while process gas outlet valve 234 is opened. A purge gas is then flowed through valve 224, the newly installed MFC and out process gas outlet 228 to the system exhaust, as shown in Figure 4b. Once the new MFC is sufficiently decontaminated, local upstream purge valve 224 is closed. Once upstream purge valve 224 is completely closed, the actuator opens process gas inlet valve 222. At this time, quick change apparatus 200 is once again in the normal mode of operation. At this time the new MFC can be used in a standard manner.

As is evident from Figure 6b, the quick change apparatus of the present invention allows for a fast and efficient purging, testing, removal, and decontamination of an MFCs without effecting other components of the gas panel to which it is attached. Additionally, by using an actuator to control the positions of the valves in quick change apparatus 200 potential hazards due to operator error are eliminated.

Figure 7a is an illustration of actuator 700 which can be used to open and close valves in the manner described with respect to timing diagrams shown in Figures 6a and 6b. Actuator 700 includes an actuator cam 702. Actuator cam 702 has a path 704 with a lobe 706.

Riding within path 704 of actuator cam 702 is a pin 707 rigidly coupled perpendicularly to a stem lever 708 which in turn is coupled to a stem 709 of valve 222. Also riding within path 704 of cam 702 is a pin 710 rigidly coupled perpendicularly to a stem lever 712 which in turn is coupled to a stem 713 of valve 224. An over center spring 714 holds stem levers 708 and 712 in their initial positions.

In Figure 7a, process gas inlet valve 222 is shown in the open position and local upstream purge valve 224 is shown in the closed position. By rotating actuator cam 702 in a counterclockwise direction, lobe 706 catches pin 707 of stem lever 708 and closes valve 222 by rotating stem lever 708 approximately 90° clockwise. As the lever rotates past the halfway position (approximately 45°) over center spring 714 assists in carrying the lever through its travel. Once the lever has reached its fully closed position, over center spring 714 holds the lever in its final position. As actuator cam 702 continues to rotate in a counterclockwise direction, lobe 706 catches pin 710 and opens valve 224 by rotating stem lever 712 approximately 90° in the clockwise direction. By simply reversing the direction of rotation of actuator cam 702, the stem levers and stems reverse their directions, initiating the closing of valve 224 and the subsequent opening of valve 222.

It is to be appreciated that path 704 of actuator cam 702 controls the positions (open/closed) of two valves, valves 222 and 224. The position of each valve at any time is controlled by the initial position of the valve stem lever and the cam lobe. In the present invention,

actuator cam 702 has a second path with a second cam lobe located in a different position to control the opening and closing of valves 234 and 236. It is to be appreciated that by adjusting the respective position of lobes and stem levers in the present invention, the opening and closing of valves can be programmed in any manner desired. It is to be appreciated that "programs", other than those shown in Figure 6a and 6b, can be generated to control the opening and closing of valves 222, 224, 234, and 236.

Figure 7b is an illustration of how actuator 700 can be implemented into quick change apparatus 200. In the preferred embodiment of the present invention, actuator cam 702 is positioned between input block 204 and output block 206. Stems and stem levers of the valves extend from respective input and output blocks, as shown in Figure 7b. An actuator cam shaft 720 extends through output block 206 (as shown by the cut away of block 206). By rotating actuator cam shaft 720, actuator cam 702 is rotated, causing the opening and closing of valves 222, 224, 234, and 236. Shown in Figure 7b is path 722 and lobe 724 which control the opening and closing of valves 234 and 236. On the opposite side of actuator cam 702 is path 704 (not shown) and lobe 706 (not shown) which controls the movement of valve stems 712 and 708 (not shown), and thus, the opening and closing of valves 224 and 222, respectfully.

Although the present invention has been described with reference to specific exemplary embodiments, it will be evident that various modifications and changes may be made to these

embodiments without departing from the broader spirit and scope of the invention as set forth in the claims. Accordingly, the specification and drawings are to be regarded in an illustrative rather than a restrictive sense.

Thus, novel methods and apparatuses have been described which provide a local and fast purging of an MFC and in place testing of an MFC.

IN THE CLAIMS

We claim:

1. A quick change apparatus for a mass flow controller comprising:

a process gas inlet for providing a first process gas to said apparatus;

an MFC outlet for providing gas from said apparatus to an input of a mass flow controller;

an upstream purge line located upstream from said MFC, said upstream purge line for providing a purge gas to said apparatus;

first means for coupling said process gas inlet to said MFC outlet and for isolating said upstream purge line from said MFC outlet, and for alternatively coupling said upstream purge line to said MFC outlet and isolating said process gas inlet from said MFC outlet;

MFC inlet for providing gas to said apparatus from an output of said MFC;

a process outlet for outputting said gas from said apparatus to a process chamber; and

second means for preventing gas flow from said process outlet to said MFC inlet and for allowing gas flow from said MFC inlet to said process outlet.

2. The apparatus of claim 1 wherein said quick change apparatus has a width of less than or equal to 1.50 inches and a length less than or equal to 4.88 inches.

3. The apparatus of claim 1 further comprising:
a downstream purge line coupled downstream from said MFC; and third means for coupling said downstream purge line to said MFC inlet and for alternatively isolating said downstream purge line from said MFC inlet and said process outlet.

4. The apparatus of claim 1 wherein said first means comprises two two-way valves.

5. The apparatus of claim 1 wherein said first means comprises a three-way valve.

6. The apparatus of claim 1 wherein said second means comprises a valve.

7. The apparatus of claim 1 further comprising a first stainless steel block for housing said process gas inlet, said MFC outlet, said upstream purge line and said first means and a second stainless steel block for housing said MFC inlet, said process outlet, and said second means, and wherein said inlets and said outlets are drilled passages in said stainless steel blocks.

8. The apparatus of claim 7 wherein said first and second stainless steel housing blocks are symmetrical.

9. The appartus of claim 1 further comprising an actuator for controlling said first and second means.

10. The actuator of claim 9 wherin said actuator prevents coupling of said upstream purge line to said MFC outlet prior to isolating process gas inlet from said MFC outlet and prevents the coupling of said process gas inlet to said MFC outlet prior to isolating said upstream purge line from said MFC outlet.

11. A gas delivery system for semiconductor process equipment comprising:

a first inlet for a first process gas;

a second inlet for a second process gas;

a first mass flow controller (MFC) for said first process gas;

a second mass flow controller (MFC) for said second process gas;

a process gas feed line for feeding said first and said second process gases to a process area;

a first source gas valve for isolating said first inlet from said first MFC;

a second source gas valve for isolating said second inlet from said second MFC;

first means located downstream of said first source gas valve and located upstream of said process gas feed line, said first means having an isolation mode for isolating said first MFC from said first inlet and from said process gas feed line, an operational mode for coupling said first inlet to said process gas feed line through said first MFC, and a local purge mode for isolating said first MFC from said first inlet and locally coupling a purge gas to said first MFC for purging said first MFC; and

second means located downstream of said second source gas valve and located upstream of said process gas feed line, said second means having an isolation mode for isolating said second MFC from said second inlet and from said process gas feed line, an operational mode for coupling said second inlet to said process feed line through said second MFC, and a local purge mode for isolating said second MFC from said second inlet and locally coupling a purge gas to said second MFC for purging said second MFC.

12. The gas panel of claim 11 wherein said first means has a width less than or equal to 1.50 inches and a length less than or equal to 4.88 inches.

13. A method of removing an MFC from a gas panel comprising the steps of:

locally isolating said MFC from a first source of gas;

coupling a purge gas to said MFC;

flowing said purge gas through said MFC to purge said MFC; and

removing said MFC from said gas panel after purging said MFC.

14. The method of claim 13 wherein said MFC is isolated downstream of a source gas valve located in said gas panel.

15. The method of claim 13 further comprising the steps of:

exhausting said purge gas through a process gas feed line, and then isolating said MFC from said process gas feed line prior to removing said MFC.

16. The method of claim 13 further comprising the steps of:

a) creating a vacuum in said MFC after flowing said purge gas through said MFC; and

b) after said step of creating a vacuum, flowing said purge gas through said MFC again.

17. The method of claim 16 further comprising the steps of:

repeating said steps a) and b) for a predetermined number of times.

18. The method of claim 11 further comprising the steps of:

isolating said MFC from a process gas feed line; and

exhausting said purge gas through a local purge line upstream of said isolation of said process gas feed line.

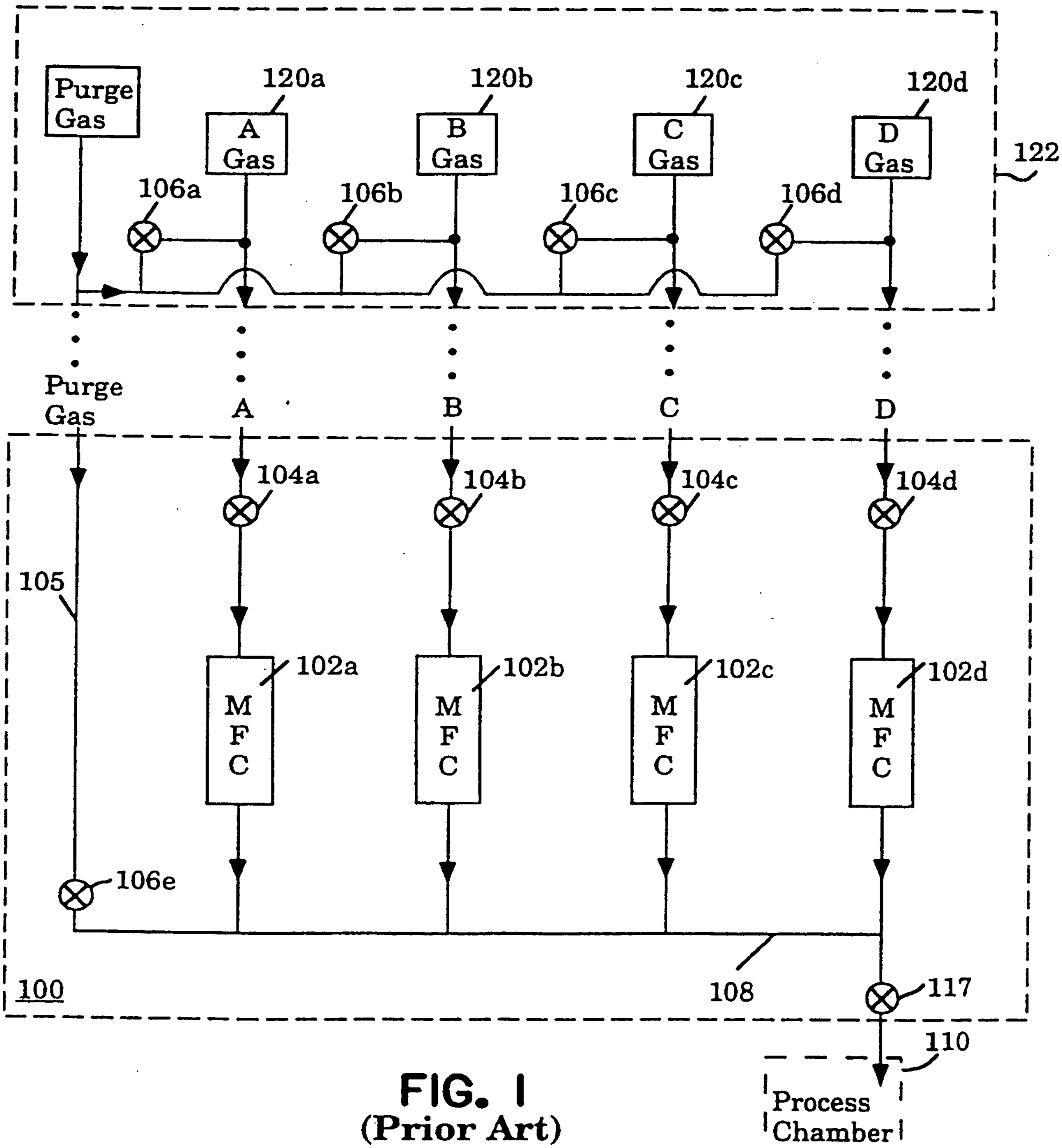


FIG. 1
(Prior Art)

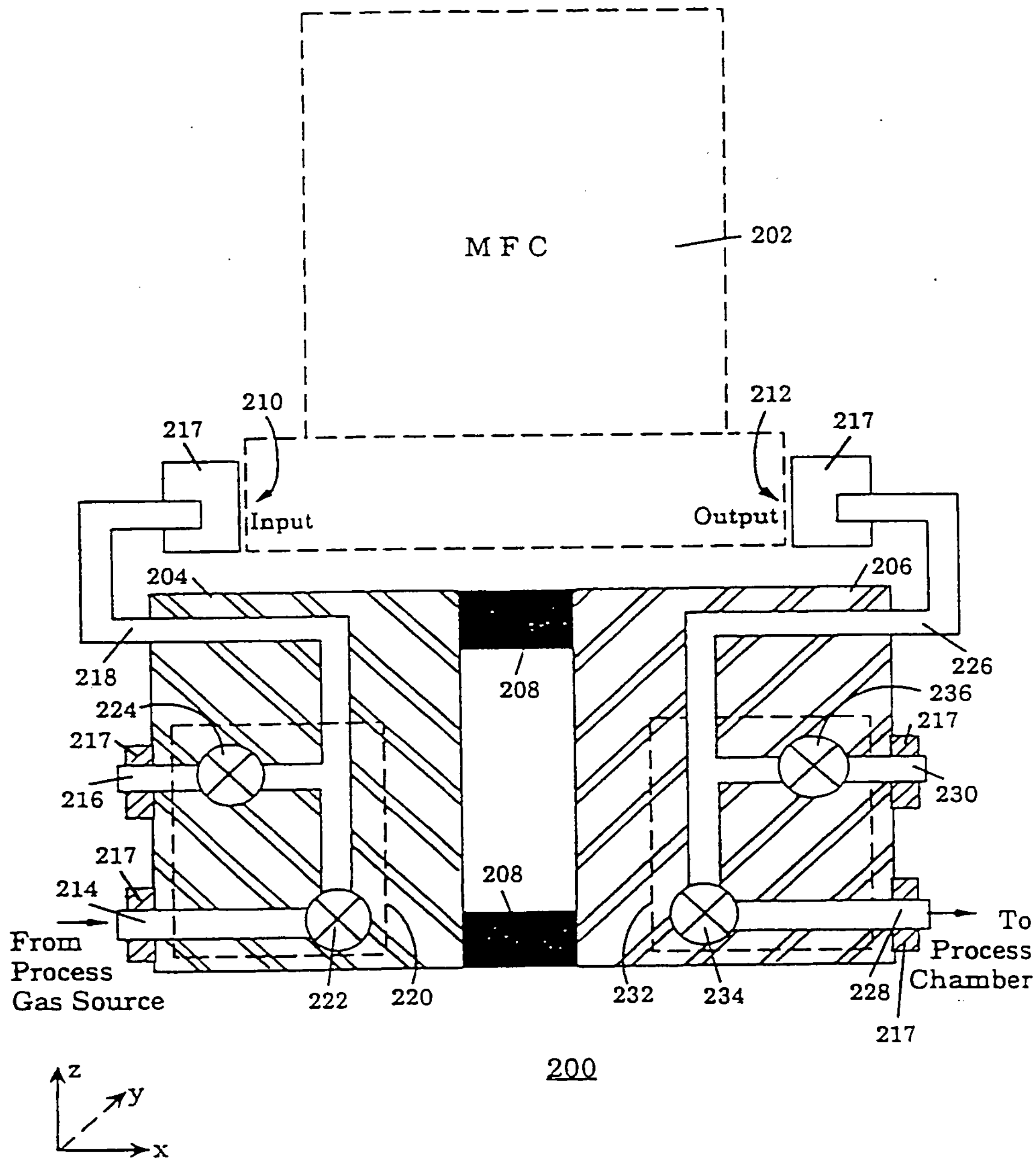

MFC
202
210
212
217
Input
Output
217
204
206
208
218
226
224
236
217
217
216
230
217
208
214
From
Process
Gas Source
To
Process
Chamber
222
220
232
234
228
217
200
z
y
x

Figure 2

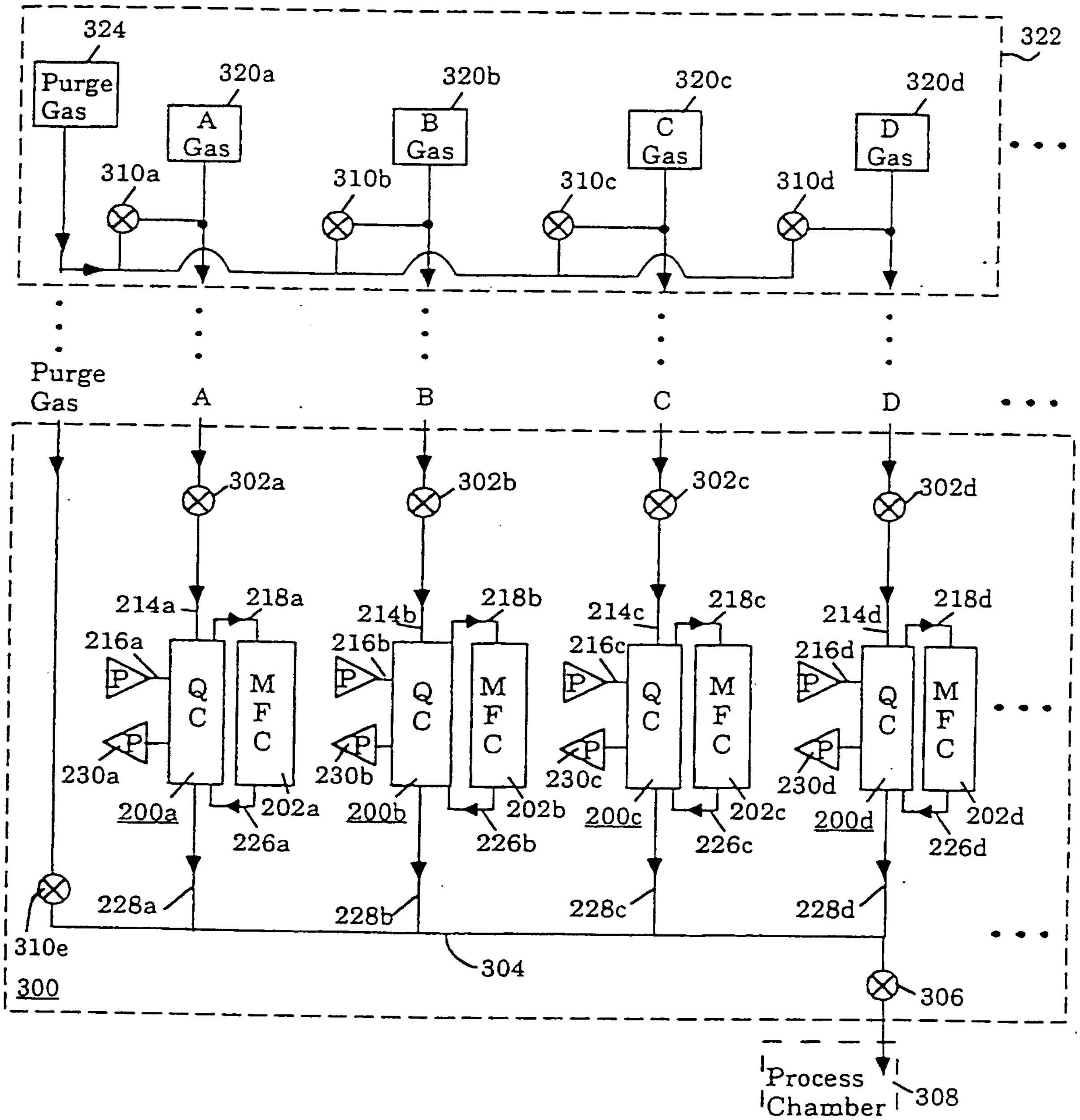
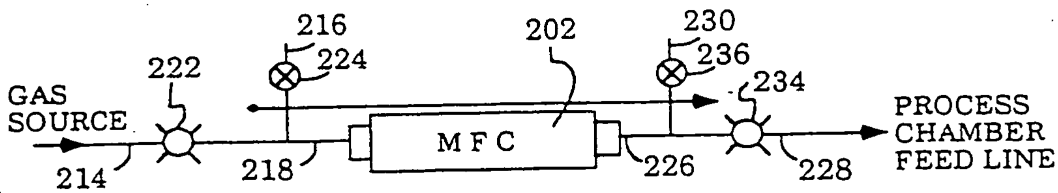
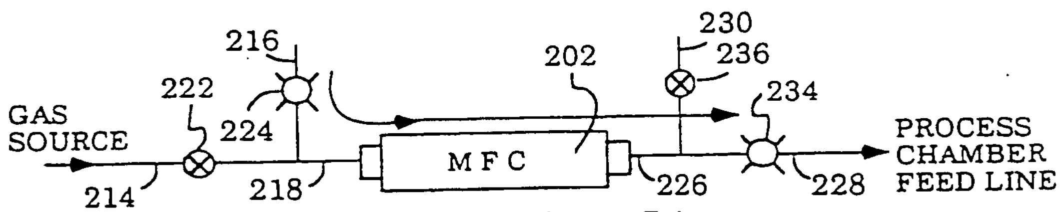

324
Purge Gas
320a
A Gas
320b
B Gas
320c
C Gas
320d
D Gas
322
310a
310b
310c
310d
Purge Gas
A
B
C
D
302a
302b
302c
302d
214a
218a
214b
218b
214c
218c
214d
218d
216a
216b
216c
216d
P
Q C
M F C
230a
230b
230c
230d
200a
202a
200b
202b
200c
202c
200d
202d
226a
226b
226c
226d
228a
228b
228c
228d
310e
300
304
306
Process Chamber
308

Figure 3



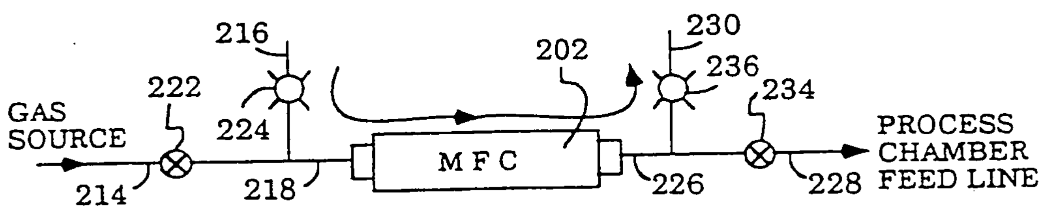
Normal Operation - Flow Through

Figure 4a



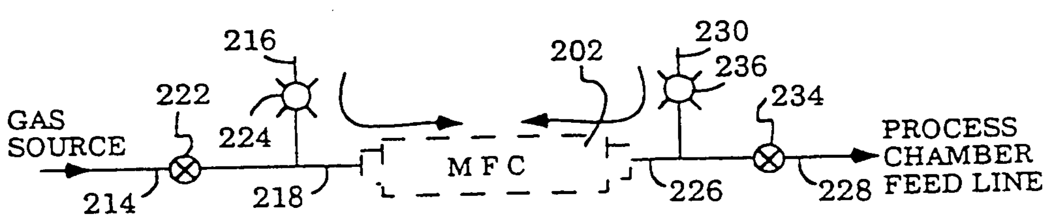
Purge/Test MFC to System Exhaust

Figure 4b



Purge/Test MFC (no exhaust)

Figure 4c



Remove MFC

Figure 4d

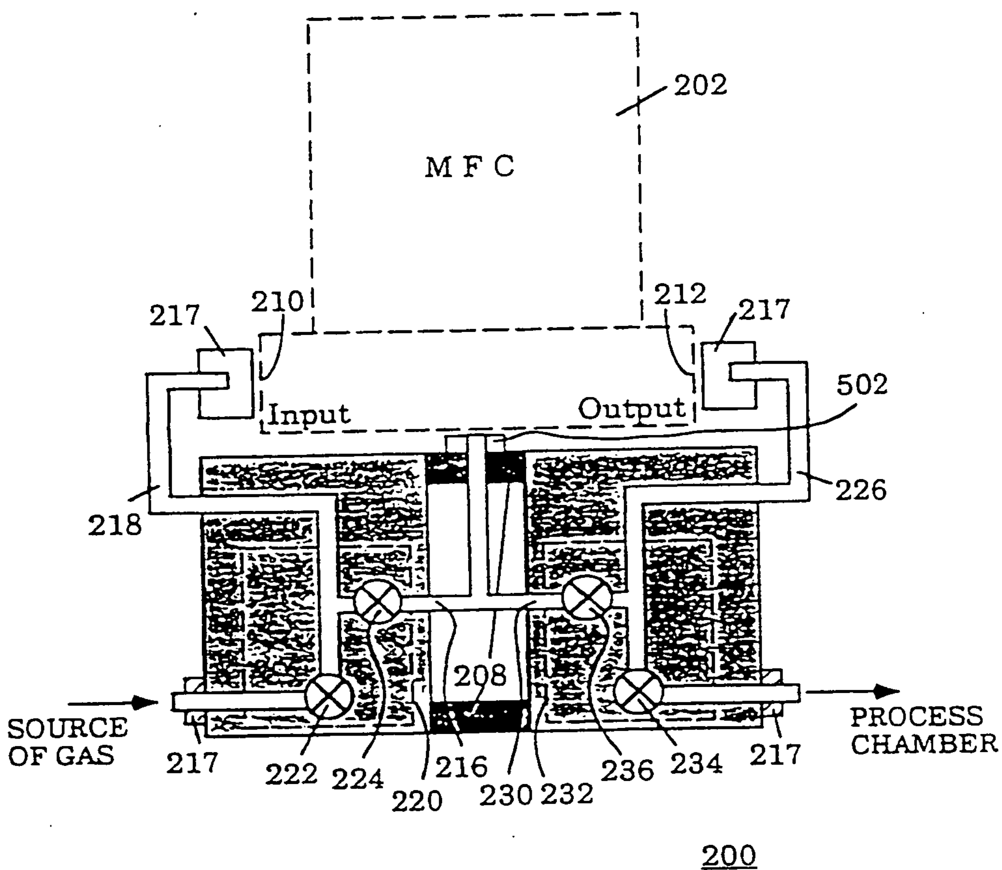

MFC
202
210
212
217
217
Input
Output
502
218
226
208
SOURCE
OF GAS
217
222
224
220
216
230
232
236
234
217
PROCESS
CHAMBER
200

Figure 5

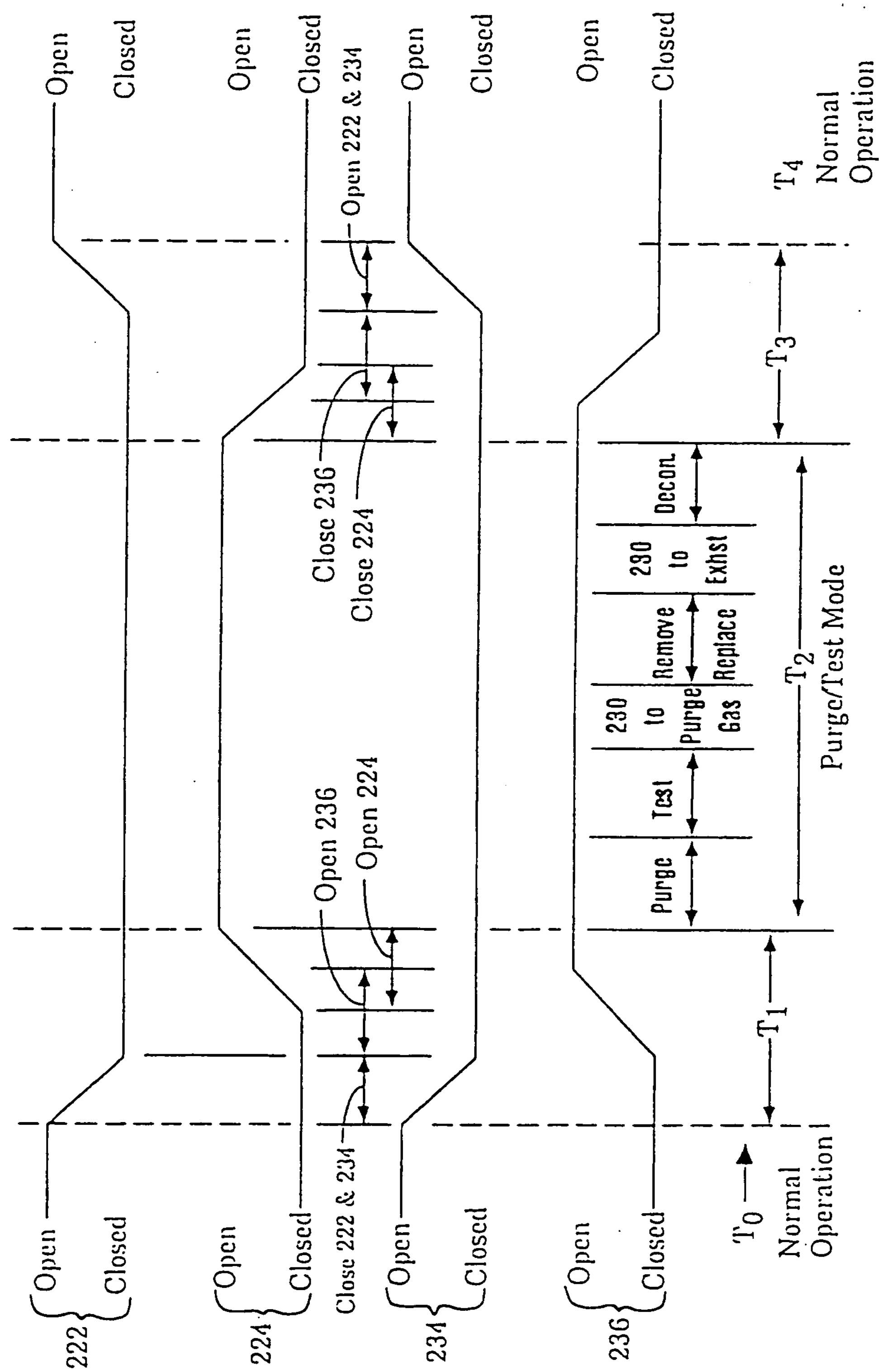

222
224
234
236
Open
Closed
Close 222 & 234
Open 236
Open 224
Close 236
Close 224
Open 222 & 234
Purge
Test
230 to Purge Gas
Remove Replace
230 to Exhst
Decon.
T0
Normal Operation
T1
T2
Purge/Test Mode
T3
T4
Normal Operation

Figure 6a

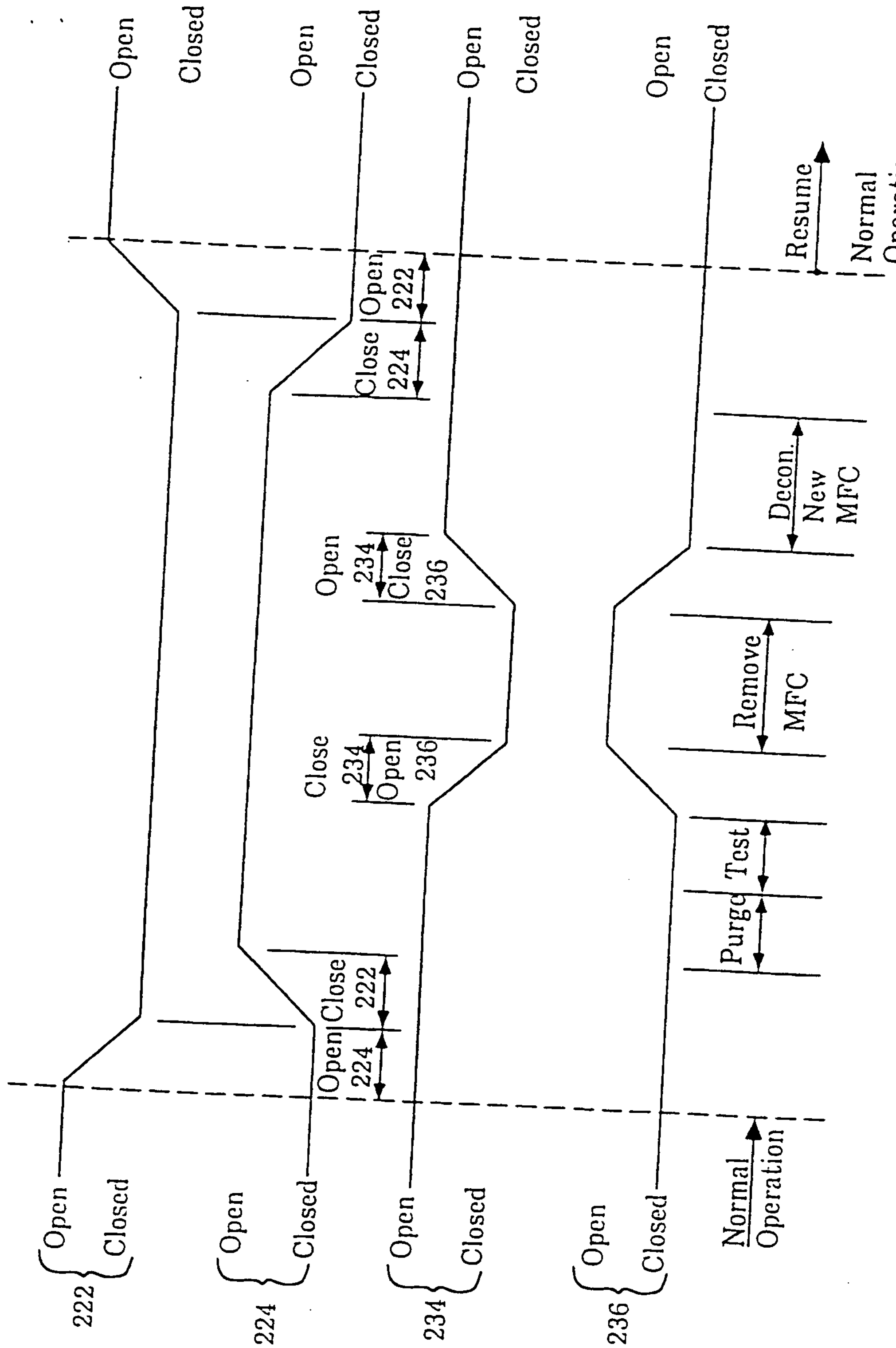

222
224
234
236
Open
Closed
Normal Operation
Open 224
Close 222
Purge
Test
Close 234
Open 236
Remove MFC
Open 234
Close 236
Decon. New MFC
Close 224
Open 222
Resume
Normal Operation

Figure 6b

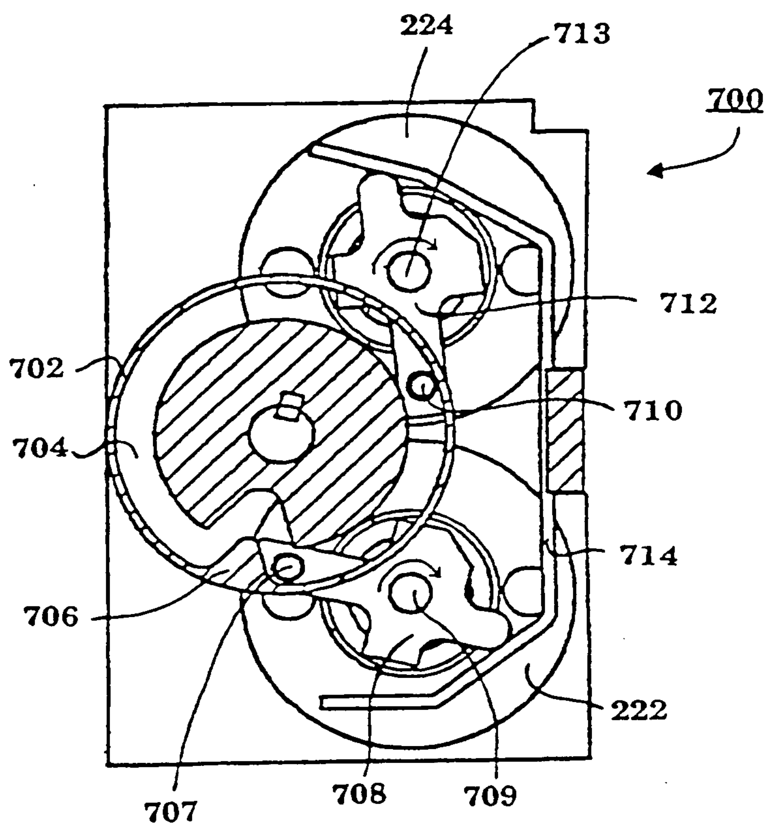


Figure 7a

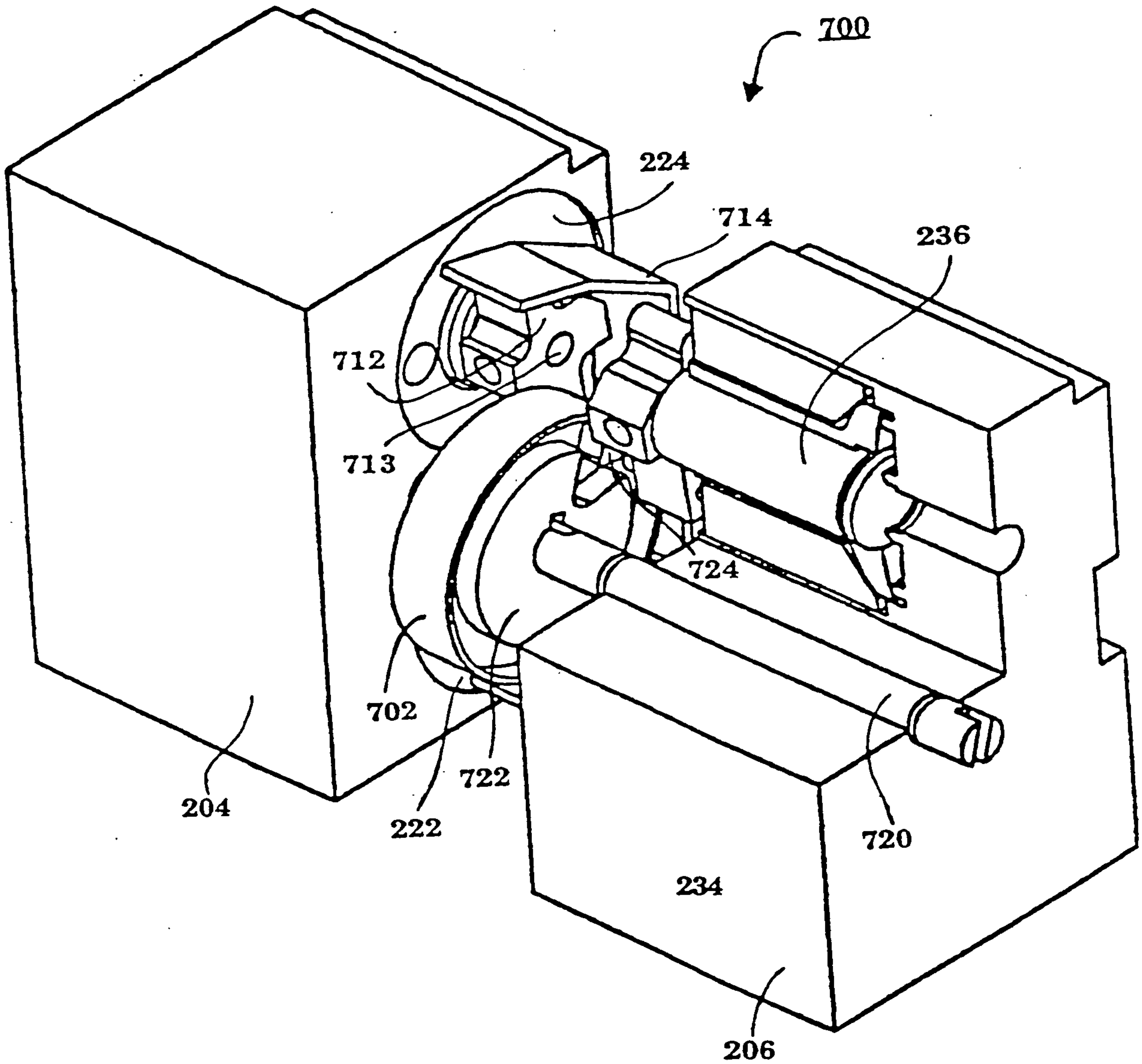


Figure 7b

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/04708

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :B08B 9/02; F 16K 11/10
US CL :137/209, 240, 271, 606, 884; 134/166C, 169R; 222/148
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 137/209, 240, 271, 606, 884; 134/166C, 169R; 222/148

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 4,741,354 (DEMILD, JR.) 03 May 1988.	1-18
A	US, A, 4,869,301 (OHMI ET AL) 26 September 1989.	1-18
A	US, A, 4,917,136 (OHMI ET AL) 17 April 1990.	1-18
A	US, A, 5,368,062 (OKUMURA ET AL) 29 November 1994, see entire document.	1-18

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 23 JUNE 1996	Date of mailing of the international search report 15 JUL 1996
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer Stacia Sinnit for GEORGE L. WALTON Telephone No. (703) 308-2596